SECONDARY ELECTRON EMISSION OF TUNGSTEN, COPPER, AND IRON AT HIGH POTENTIALS.

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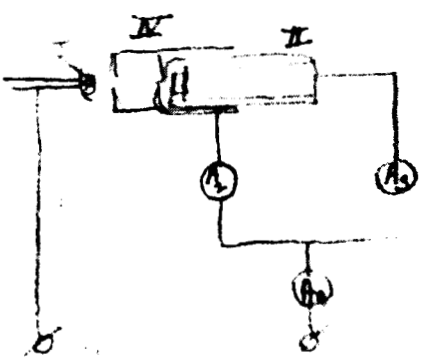
Introduction

Very few papers have been devoted to the study of secondary emission at high voltages. Lately, knowledge of the mechanism of such emission is becoming very important in physics and electronics. This paper describes results of measurements of coefficients of secondary emission from several metals at voltages up to 70 Kv., and also results of measurements of distribution of secondary emission from tungsten in velocity and angle of departure.

1. Methods of Measurements

The device used for measurements of σ is of the type used by Farnsworth but somewhat modified. Its general arrangement is shown in Fig. 1. The main difference in our case is the presence of two diaphragms in the anode, which forms a Faraday space in the front of the mirror made of material under investigation. This space allows secondary electrons to leave it without obstruction.



I - cathode
II - Faraday cylinder
III - emitter of sec. el.
IV - collector

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Fig. 1

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The device consists of electro gun (1), Faraday cylinder (2) with diaphragm and a free moving plate (3) made of the material under investigation, and a cover with two diaphragms (4) to collect secondary electrons. A regular cathode used in a normal X-ray tube with round focus was utilized. Measurement showed that at voltages over 5kv. satisfactory focusing is obtained and hardly any of the primary electrons reach diaphragm (4).

Diagram of connections is shown in the Fig. 1. Ammeter A_1 reads full anode current, A_2 reads secondary anode current. Mirror (3) may be moved by its own weight along cylinder (2). When it is located at the bottom of the cylinder no secondary electrons may leave the cylinder (2), while A_2 as well as A_1 reads full anode current. If the mirror is located near the front diaphragm of the cylinder then all secondary electrons may be caught by the electrode (4). In the meantime, A_2 will show secondary electron current, while A_3 is the difference between primary and secondary currents. A_1 as before will show full anode current. Difference of readings of the ammeter A_3 at two positions of the mirror ($I_1 - I_2$) indicates the magnitude of the secondary electron currents which gives directly the value of the coefficients.

The accuracies of the above method is sufficiently high, which is verified by the fact that similar measurements made on several experimental tubes give precisely the same results.

Fig. 2

Construction of test tube - Pg. 87.

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To measure distribution of secondary electrons in angle of departure, a device was constructed as shown in fig. 2. Here a cathode (1), consisting of a solid focusing cup with incandescent spiral at the center of its base, serves as a source of primary electrons. They enter an accelerating field between the cathode and conical head of anode (2). On reaching the velocity determined by the anode potential, the electrons go through a narrow throat in the head (2) and into a sphere (4) here they strike a mirror of material under investigation, welded to the end of the anode (6). Because of the head (2) and the sphere (4), the secondary electrons disperse in the Faraday space without any external disturbing influence. Sphere (4) has a narrow longitudinal slot for passing secondary electrons in the direction of a collector (9). The surface of the latter facing sphere (4), is made concentric to this sphere, so that between the two forms a spherical field. The collector is made in a form of a box, and on the collecting surface it has an opening opposite the opening of the sphere (4) to receive the beam of the secondary electrons. This was made to eliminate the effect of the emission from the collector caused by the bombarding secondaries on the accuracy of the measurement.

For measurements of distribution of secondaries with the angle of departure, one must have means of measuring secondary emission in various solid angles of the same magnitude. For this purpose, the sphere (4) has a spherical cap (8) which can turn on the neck of a weight (3). The cap (8) possesses openings distributed in such a way, that when cap turns, one may successively open various portions of the slot in the sphere (4), while other portions of the slot are closed. In this way, while measuring currents to the collector from various openings, one may judge the relative number of electrons leaving material along given directions. Anode (6) as well as the cup (10) which supports the collector (9) are carrying nichrome cones for attaching them to the glass vessel. Inside the collector is placed a spiral (11) for heating it during degassing.

The sphere (4) is made of solid copper and is attached to the anode (5) by means of a ring (5). The external screening cap (8) is of thin sheet nickel. Since the friction between copper and nickel in vacuum is found to be considerable, the neck of the anode head carries an iron bushing around which turns the cap (8). The weight (3) is made folding to insert it through a narrow tube before sealing it. Figure (3) shows the photograph of the tube. (Pg. 812 of text)

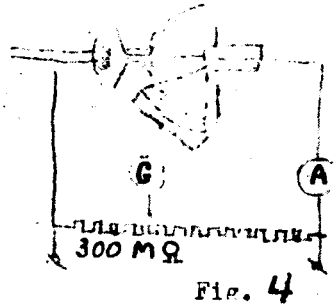

Fig. 4

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The diagram used in measurements is shown in Fig. 4. Parallel to the device was connected a potentiometer having resistance of 300 megohms. The collector with an ammeter and sliding contact may be connected to any part of the potentiometer, which gives it any desired potential. The magnitude of current flowing to the collector is negligible compared to the current flowing through the potentiometer and its effect on the potential of the collector is negligible.

As usual in measurements at high voltages, it was necessary to take special care in shielding of instruments and take into account leakages.

For every value measured, leakage currents were measured with the slot of the sphere covered, and the value of leakage was subtracted from the value read before. With above precautions, the values measured may be considered very close to true values.

Results of Measurements

The measurements were made at anode potentials from 5 kv to 75kv. Four metals were studied--tungsten, copper, iron and Farrachromium. In Fig. 5

are shown several curves which showed the iependence of σ of these metals on the velocity of primary electrons. It is seen that the previously known dependence, that σ increases with the atomic number, is confirmed.

Pg. 873

Fig. 5

The curves show that the largest σ is possessed by tungsten, then follows copper, iron and Farrachromium, the latter two having almost identical σ .. In the interval of primary velocities which we studied σ decreases with primary velocity increasing. Between 5 and 10Kv, the decrease is rapid. Between 50 and 70 Kv., the curves show a practical independence of σ from the velocity of the primaries. The minimal value of σ for various metals is definite and is 55% for tungsten, 37% for copper and 25% for iron and Farrachromium. It is interesting to note that measurements on Farrachromium in different stages of its oxiidation showed less than 6% change.

The space distribution of secondary electrons from tungsten was studied with normal incidence of the primary beam at voltages between 30 and 50 Kv. Measurements were made every 6.5°, beginning with an angle with the surface of the mirror of 0° and ending at 65°. The limiting angle at which the instrument permitted measurements (65°) was determined by the construction. In Fig. 6 are shown distribution of secondaries in angle of departure (in relative units) with primary velocities of 30, 40 and 50Kv.

It appears that with the primary velocity increasing, the number of secondaries departing at large angle to the surface of the mirror is also increasing. The space distribution of secondaries changes little in the range of potentials used. The angular distribution at first approximation is proportional to the

sine of the angle of departure. To demonstrate the above effect in Fig. 6 a circle is drawn tangent to the mirror and passing through the interception of the curves.

Measurements of velocity distribution of secondary emission were made with the slot in the anode cap open and at potentials from 20 to 50 Kv. In this way the distribution of velocities (speed) were studied irrespectively of the angle of departure. A retarding potential was impressed on the collector with respect to the anode and current to the collector was measured. After corrections, the characteristic of the collector was obtained, from which by numerical differential distribution of velocities was obtained. The collector characteristics are shown in Fig. 7.

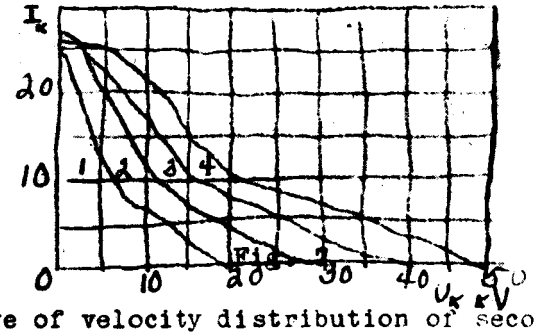

Fig 7

(Fig 8)

Fig. 8 shows the curve of velocity distribution of secondary electrons (anode potential of 40 Kv.) calculated from the collector characteristic. Curves of this type have two maxima; large sharp maximum in the region of velocity around 1/5 of primary velocities and another maximum not so sharply pronounced - in the order of 9/10 of the primary.

Using the same arrangement as with the above velocity distribution measurements, we studied velocity distribution of secondary electrons having a definite angle of departure. In Fig. 9 are shown collector characteristics of electrons departing at 9.2, 22.3, 35.1, and 47.9, at anode potential of 20 Kv. It is seen that the general characteristic of velocity distribution for various angles of departure differs considerably.

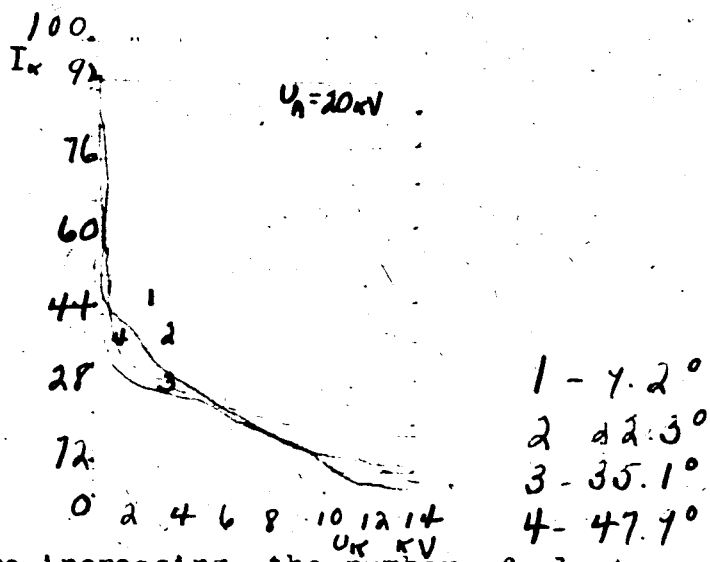

Fig. 9

With the angle of departure increasing, the number of electrons having high velocities are sharply increasing. At angles smaller than 10°, the curves show that they are hardly electrons with velocities larger than 50% the primary. The latter measurements are rather difficult to perform. The currents, resulting in separating electrons departing in a small solid angle and separating again only the ones having a particular velocity are exceedingly small. Measurements of such currents especially accounting for all the leakage currents always occurring at high voltage measurements, are extremely difficult.

Conclusions

1. Methods of measurements described above, appear to be accurate and relatively simple.

2. When primary velocity increases (at potentials higher than 5Kv.) σ gradually decreases, reaching a certain minimal value changing very little with further increase of primary velocities (roughly at 50 kv.)

3. σ of metals studied, in its numerical value is in the same order as the atomic weight of the metals.

4. Space distribution of secondaries depends on the primary velocity. When the primary velocity increases, the fractions of secondary electrons departing at large angle increases.

5. For tungsten at primary velocities between 30 and 50 kv the number of secondaries departing at various angles is approximately proportional to the sine of the angle of departure with respect to the surface.

6. Secondary electrons, resulting from bombardment at high voltages have wide distribution of velocities: between 0 and up to roughly 90-95% of the primary velocity.

7. Curve of velocity distribution of secondary emission from tungsten has two maxima; one at 9/10 of velocity of the primaries and another at 2/10 of it.

8. Velocity distribution of seconderies departing at various angles varies. For tungsten with increasing the angle of departure the number of high velocity seconderies is rapidly increasing. For small angles of departure there are hardly any high velocity seconderies.